

## JOINT INVENTORS

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EL564461675US

Date of Deposit: **June 11, 2001**

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Richard Zimmermann

## APPLICATION FOR UNITED STATES LETTERS PATENT

### SPECIFICATION

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#### TO ALL WHOM IT MAY CONCERN:

Be it known that we, Min Ho JUNG, a citizen of the Republic of Korea, residing at #205-1102 SunKyoung Apt., Jeungpo-dong, Ichon-shi, Kyongki-do 467-110, Korea, and Sung Eun HONG, a citizen of the Republic of Korea, residing at #205-601 Hanshin Apt., 124 Imae-dong, Bundang-gu, Sungnam-shi, Kyongki-do 463-060, Korea, and Jae Chang JUNG, a citizen of the Republic of Korea, residing at #107-1304 Hyundai Apt., Sadong-ri, Daewol-myeon, Ichon-shi, Kyongki-do 467-850, Korea, and Geun Su LEE, a citizen of the Republic of Korea, residing at #103-302 Samick Apt., Bubal-eub, Ichon-shi, Kyongki-do 467-860, Korea, and Ki Ho BAIK, a citizen of the Republic of Korea, residing at #203-402 Daewoo Apt., Jeungpo-dong, Ichon-shi, Kyongki-do 467-860, Korea, have invented a new and useful ADDITIVE FOR PHOTORESIST COMPOSITION FOR RESIST FLOW PROCESS, of which the following is a specification.

**ADDITIVE FOR PHOTORESIST COMPOSITION  
FOR RESIST FLOW PROCESS**

**~~BACKGROUND OF THE INVENTION~~**

5        Field of the Invention

The present invention relates to an additive for a photoresist composition for a resist flow process, and a photoresist composition comprising the same. In particular, the present invention relates to a photoresist composition comprising an additive which lowers the glass transition temperature of the photoresist polymer, and a method for forming a contact hole using the same.

10        Description of the Background Art

Recently, semiconductor devices have been highly integrated. It is difficult to form a contact hole having a high resolution in lithography process. Currently, a contact hole patterning limit of KrF lithography is about 0.18 $\mu$ m. Resist flow is a processing technology for forming a fine contact hole which exceeds the resolution of the exposing device.

The resist flow process has recently made remarkable developments and so that it is now used in mass production processes. The technology generally involves an exposure process and a development process. This process forms a photoresist contact hole having a resolution equal to that of the exposing device. The process also includes heating the photoresist to a temperature higher than the glass transition temperature of the photoresist which causes the photoresist to flow. The contact hole gets smaller by the flow of photoresist until a fine contact hole necessary for the integration process is obtained.

25        Most of the KrF resists can be flow processed, though having different profiles after the flow process. That is, the KrF resist mainly containing

polyvinylphenol consists of a structure having appropriate  $T_g$  for the flow. However, a resist used for ArF lithography has so high  $T_g$  that it cannot be flow processed. Especially, cycloolefine resists have a  $T_g$  over about 200°C, and thus is not suitable for the resist flow process. An appropriate temperature for the resist flow process ranges between the  $T_g$  of the photoresist polymer and a decomposition temperature ( $T_d$ ) where the polymer starts to be decomposed. Therefore, the polymer having high  $T_g$  cannot be used for a resist flow because the  $T_g$  and  $T_d$  have only a slight difference. Therefore, there is a need for a modified resist material with a suitable disparity between the  $T_g$  and  $T_d$  thereby making it suitable for resist flow processing.

## SUMMARY OF THE DISCLOSURE

An additive for a photoresist composition thereby making it suitable for a resist flow process is disclosed.

Photoresist compositions comprising such additive for a resist flow process are also disclosed.

A resist flow process for forming a photoresist pattern using such photoresist composition is also disclosed.

A contact hole formation method employing the photoresist pattern formed by the above-described process is also disclosed.

## BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 shows a first photoresist pattern obtained in Example 11. ✓

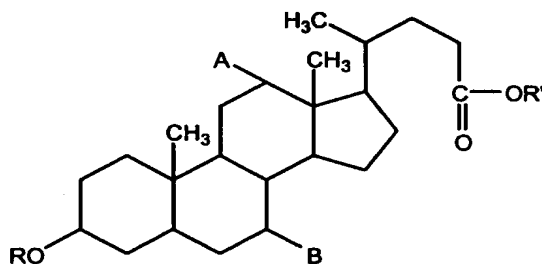
Fig. 2 shows a second photoresist pattern obtained in Example 11. ✓

## DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

5 The present invention provides an additive for a photoresist composition for a resist flow process, and a photoresist composition comprising the same. In particular, the present invention provides a photoresist composition comprising the additive which lowers the glass transition temperature of the photoresist polymer, thereby improving a flow property of photoresist composition during a resist flow process.

10 In one particular aspect, the present invention provides an additive of following Formula 1 for the photoresist composition which is used for a resist flow process:

Formula 1



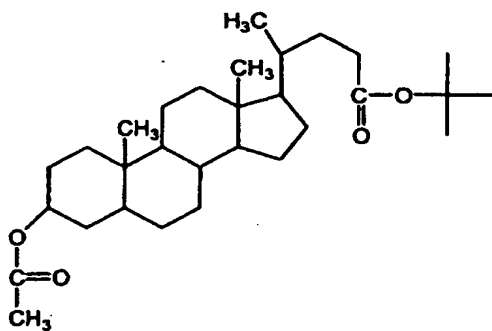
wherein, A is H or -OR",

B is H or -OR'", and

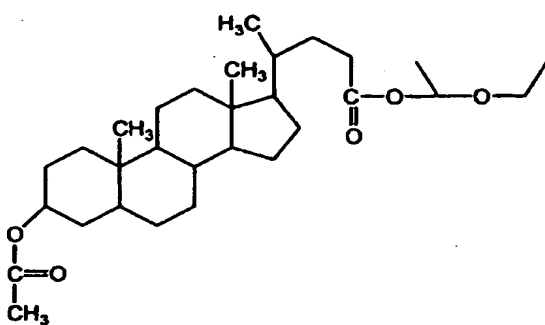
15 R, R', R" and R'" are independently substituted or unsubstituted linear or branched C<sub>1</sub>-C<sub>10</sub> alkyl, substituted or unsubstituted linear or branched C<sub>1</sub>-C<sub>10</sub> alkoxyalkyl, substituted or unsubstituted linear or branched C<sub>1</sub>-C<sub>10</sub> alkylcarbonyl, or substituted or unsubstituted linear or branched C<sub>1</sub>-C<sub>10</sub> alkyl containing at least one hydroxyl group (-OH).

20 Exemplary additives of Formula 1 include, but are not limited to, the following compounds of Formulas 2 to 7:

Formula 2

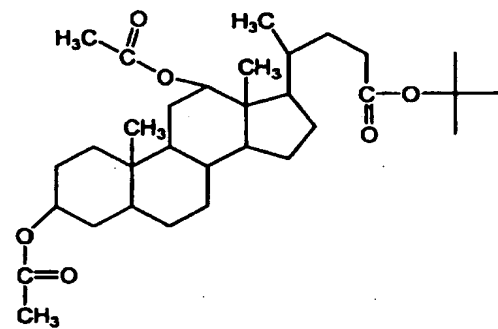


Formula 3

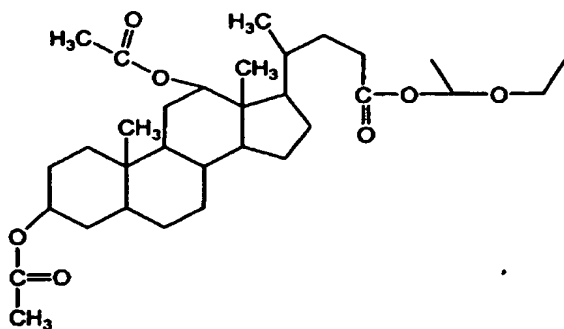


5

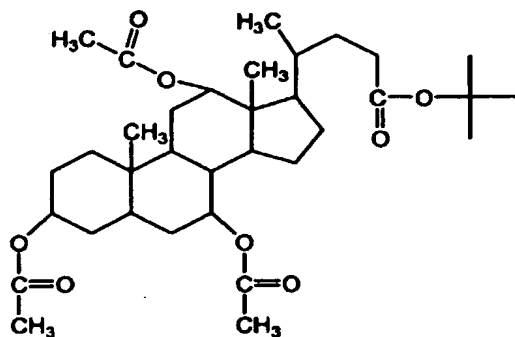
Formula 4



Formula 5

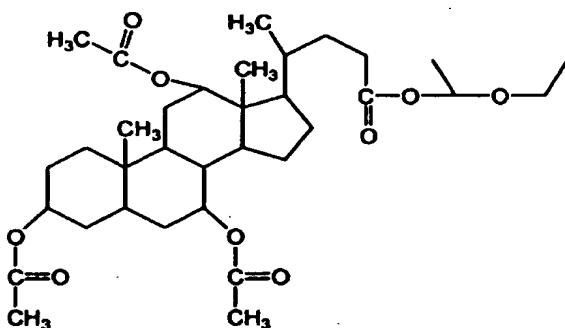


Formula 6



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Formula 7



Another aspect of the present invention provides a photoresist composition comprising a photoresist polymer, a photoacid generator, an organic solvent and the additive of Formula 1.

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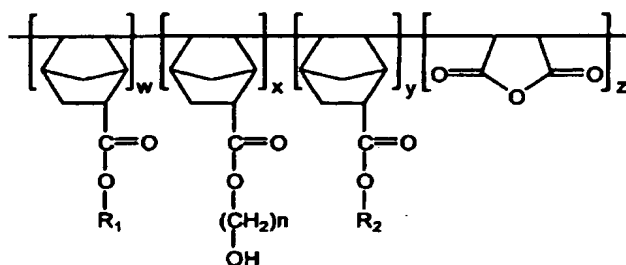
The present photoresist composition comprising the additive of Formula 1 is suitable for the resist flow process. As described above, a photoresist polymer

AS could  
 having very high glass transition temperature ( $T_g$ ) cannot be used for resist flow process since the  $T_g$  and decomposition temperature ( $T_d$ ) have only a slight difference. However, the additive of Formula 1 serves to lower the  $T_g$ , thus improving a flow property of the photoresist composition. As a result, the photoresist composition  
 5 can be suitably employed for the resist flow process.

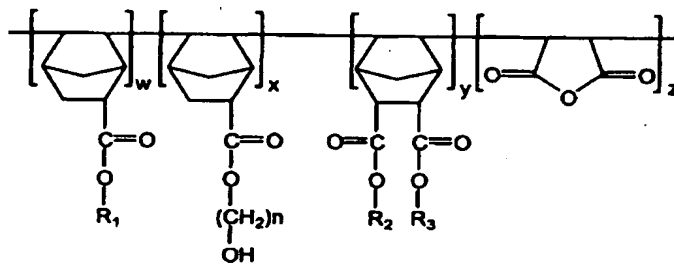
The photoresist polymer of the photoresist composition can be any currently known chemically amplified photoresist polymer disclosed in US 5,212,043 (May 18, 1993), WO 97/33198 (Sep 12, 1997), WO 96/37526 (Nov 28, 1996), EP 0 794 458 (Sep 10, 1997), EP 0789 278 (Aug 13, 1997) and US 6,132,926 (Oct 17, 2000). It is  
 10 preferable that the PR polymer be prepared by radical additional polymerization of cycloolefin comonomers and the ring structures of the cycloolefin comonomers remains in the main chain of the PR polymer. An exemplary photoresist polymer employed in the photoresist composition includes a compound of following Formulas 8 or 9:

15

Formula 8



Formula 9



wherein, R<sub>1</sub> is an acid labile protecting group;

R<sub>2</sub> is hydrogen;

R<sub>3</sub> is hydrogen, substituted or unsubstituted linear or branched C<sub>1</sub>-C<sub>10</sub> alkyl, substituted or unsubstituted linear or branched C<sub>1</sub>-C<sub>10</sub> alkoxyalkyl, or substituted or unsubstituted linear or branched C<sub>1</sub>-C<sub>10</sub> alkyl containing at least one hydroxyl group (-OH);

n is an integer from 1 to 5; and

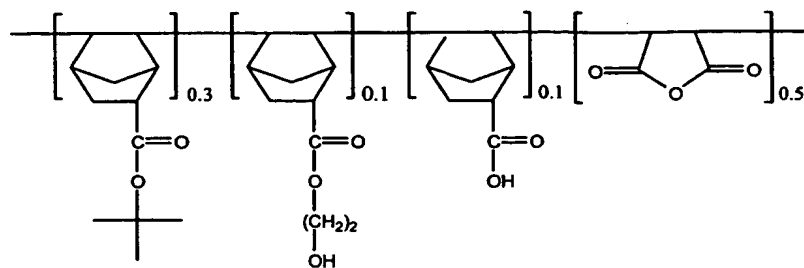
w, x, y and z individually denote the mole ratio of each monomer, preferably with proviso that w + x + y = 50mol%, and z is 50mol%.

10 The acid labile protecting group can be any of the known protective groups that can be substituted by an acid and functions to prevent the compound to which the group is bound from dissolving in the alkaline developer solution. Conventional acid labile protecting groups are disclosed in US 5,212,043 (May 18, 1993), WO 97/33198 (Sep 12, 1997), WO 96/37526 (Nov 28, 1996), EP 0 794 458 (Sep 10, 1997),  
15 EP 0789 278 (Aug 13, 1997) and US 6,132,926 (Oct 17, 2000). Preferable acid labile protecting groups are selected from the group consisting of tert-butyl, tetrahydropyran-2-yl, 2-methyl tetrahydropyran-2-yl, tetrahydrofuran-2-yl, 2-methyl tetrahydrofuran-2-yl, 1-methoxypropyl, 1-methoxy-1-methylethyl, 1-ethoxypropyl, 1-ethoxy-1-methylethyl, 1-methoxyethyl, 1-ethoxyethyl, tert-butoxyethyl, 1-  
20 isobutoxyethyl and 2-acetylmenth-1-yl.

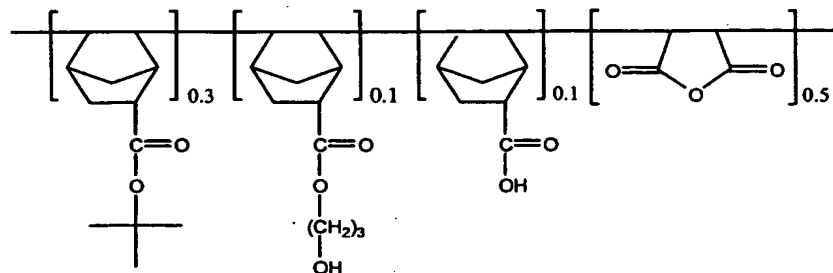
Preferably, the photoresist polymer of Formulas 8 or 9 include, but are not limited to, compounds of Formulas 10 to 13:



Formula 10

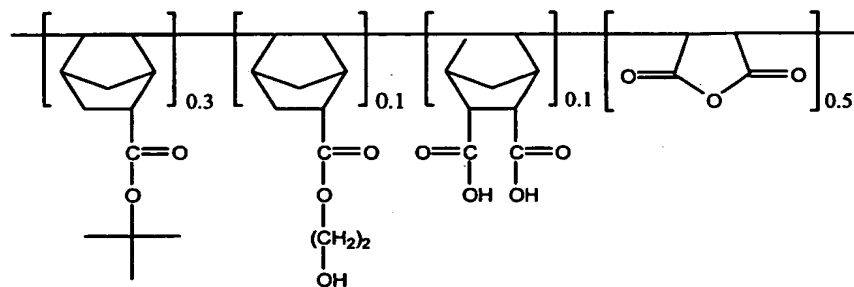


Formula 11

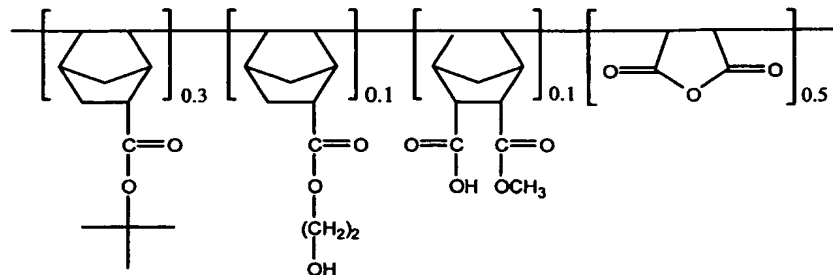


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Formula 12



Formula 13



The additive of Formula 1 is used in an amount of 1 to 70% by weight of the  
10 photoresist polymer employed.

Any of known photoacid generator, which is able to generate acids by light, can be used in photoresist composition of the present invention. Conventional photoacid generators are disclosed in US 5,212,043 (May 18, 1993), WO 97/33198 (Sep 12, 1997), WO 96/37526 (Nov 28, 1996), EP 0 794 458 (Sep 10, 1997), EP 0789 278 (Aug 13, 1997) and US 6,132,926 (Oct 17, 2000).

Preferred photoacid generators include sulfides or onium type compounds. In one particular embodiment of the present invention, the photoresist generator is at least one compound selected from the group consisting of diphenyl iodide hexafluorophosphate, diphenyl iodide hexafluoroarsenate, diphenyl iodide hexafluoroantimonate, diphenyl p-methoxyphenyl triflate, diphenyl p-toluenyl triflate, diphenyl p-isobutylphenyl triflate, diphenyl p-tert-butylphenyl triflate, triphenylsulfonium hexafluorophosphate, triphenylsulfonium hexafluoroarsenate, triphenylsulfonium hexafluoroantimonate, triphenylsulfonium triflate and dibutyl-naphthylsulfonium triflate. The photoacid generator is used in an amount ranging from about 0.01 to about 10% by weight of the photoresist polymer employed.

While a variety of organic solvents, disclosed in US 5,212,043 (May 18, 1993), WO 97/33198 (Sep 12, 1997), WO 96/37526 (Nov 28, 1996), EP 0 794 458 (Sep 10, 1997), EP 0789 278 (Aug 13, 1997) and US 6,132,926 (Oct 17, 2000), are suitable for use in the photoresist composition of the present invention, the organic solvent selected from the group consisting of propyleneglycol methyl ether acetate, ethyl lactate, methyl 3-methoxypropionate, ethyl 3-ethoxypropionate and cyclohexanone is preferred. The amount of solvent used is preferably in the range of from about 100% to 1000% by weight of the photoresist polymer.

A process is also disclosed for forming a photoresist pattern, by introducing the resist flow process and using the photoresist composition containing the additive of Formula 1.

The process for forming the photoresist pattern comprises the steps of:

(a) coating the above described photoresist composition containing the additive of Formula 1 on a substrate to form a photoresist film;

(b) forming a first photoresist pattern using a lithography process (preferably the first photoresist pattern has a lower resolution than the maximum resolution of an exposing device); and

(c) producing a second photoresist pattern from the first photoresist pattern using a resist flow (i.e., flow bake) process.

Preferably, the second photoresist pattern has a higher resolution than the first photoresist pattern. More preferably, the second photoresist pattern has a higher resolution than the maximum resolution of the exposing device of the step (b).

The temperature of the resist flow process of step (c) is preferably in the range of from about 120 to about 190 °C.

A method is also disclosed for preparing a contact hole using the photoresist composition described above. In particular, a substrate coated with the photoresist composition of the present invention is etched using the second photoresist pattern (as described above) as an etching mask to form the contact hole.

Yet another embodiment provides a semiconductor element that is manufactured using the photoresist composition described above.

The present invention will now be described in more detail by referring to the examples below, which are not intended to be limiting.

#### **I. Synthesis of Additive**

##### Example 1--Synthesis of Compound of Formula 2

To tetrahydrofuran was added 0.1 mole of lithocholic acid and 0.1 mole of triethylamine, and the resulting solution was maintained at a temperature below 4°C in an ice bath. 0.12 mole of acetyl chloride was slowly added thereto, and the

resulting solution was reacted for 8 hours. Thereafter, residual solvent was removed by using a vacuum distillator. A compound was extracted by using ethyl acetate, and washed with water a few times, to obtain 3 $\alpha$ -acetylcholanic acid. To tetrahydrofuran was added 0.2 mole of 3 $\alpha$ -acetylcholanic acid thus obtained and 0.3 mole of acetic anhydride. 0.21 mole of tert-butanol was added to the resulting solution. Then, the resulting solution was reacted for 12 hours, to obtain 3 $\alpha$ -acetyl tert-butyl lithocholate of formula 2 (yield : 68%).

#### Example 2--Synthesis of Compound of Formula 3

To tetrahydrofuran was added 0.1 mole of lithocholic acid and 0.1 mole of triethylamine, and the resulting solution was maintained at a temperature below 4°C in an ice bath. 0.12 mole of acetyl chloride was slowly added thereto, and the resulting solution was reacted for 8 hours. Thereafter, residual solvent was removed by using a vacuum distillator. A compound was extracted by using ethyl acetate, and washed with water a few times, to obtain 3 $\alpha$ -acetylcholanic acid. To tetrahydrofuran was added 0.2 mole of 3 $\alpha$ -acetylcholanic acid thus obtained and a slight amount of p-toluensulfonic acid. 0.21 mole of ethylvinylether was added to the resulting solution. Then, the resulting solution was reacted for 12 hours, to obtain 3 $\alpha$ -acetylethoxyethyl lithocholate of formula 3 (yield : 70%).

#### Example 3--Synthesis of Compound of Formula 4

To tetrahydrofuran was added 0.1 mole of lithocholic acid and 0.1 mole of triethylamine, and the resulting solution was maintained at a temperature below 4°C in an ice bath. 0.24 mole of acetyl chloride was slowly added thereto, and the resulting solution was reacted for 8 hours. Thereafter, residual solvent was removed by using a vacuum distillator. A compound was extracted by using ethyl acetate, and washed with water a few times, to obtain 3 $\alpha$ ,10 $\alpha$ -diacetylcholanic acid. To tetrahydrofuran was added 0.2 mole of 3 $\alpha$ ,10 $\alpha$ -diacetylcholanic acid thus obtained

and 0.3 mole of acetic anhydride. 0.21 mole of tert-butanol was added to the resulting solution. Then, the resulting solution was reacted for 12 hours, to obtain 3 $\alpha$ ,10 $\alpha$ -diacetyl tert-butyl lithocholate of formula 4 (yield : 69%).

#### Example 4--Synthesis of Compound of Formula 5

- 5        The procedure of Example 2 was repeated but using 3 $\alpha$ ,10 $\alpha$ -diacetylcholanolic acid obtained in Example 3, instead of 3 $\alpha$ -acetylcholanolic acid, to obtain 3 $\alpha$ ,10 $\alpha$ -diacetyloxyethyl lithocholate of formula 5 (yield : 72%).

#### Example 5--Synthesis of Compound of Formula 6

- 10        To tetrahydrofuran was added 0.1 mole of lithocholic acid and 0.1 mole of triethylamine, and the resulting solution was maintained at a temperature below 4°C in an ice bath. 0.36 mole of acetyl chloride was slowly added thereto, and the resulting solution was reacted for 8 hours. Thereafter, residual solvent was removed by using a vacuum distillator. A compound was extracted by using ethyl acetate, and washed with water a few times, to obtain 3 $\alpha$ ,5 $\alpha$ ,10 $\alpha$ -triacetylcholanolic acid. To  
15        tetrahydrofuran was added 0.2 mole of 3 $\alpha$ ,5 $\alpha$ ,10 $\alpha$ -triacetylcholanolic acid thus obtained and 0.3 mole of acetic anhydride. 0.21 mole of tert-butanol was added to the resulting solution. Then, the resulting solution was reacted for 12 hours, to obtain 3 $\alpha$ ,5 $\alpha$ ,10 $\alpha$ -triacetyl tert-butyl lithocholate of formula 6 (yield : 70%).

#### Example 6--Synthesis of Compound of Formula 7

- 20        The procedure of Example 2 was repeated but using 3 $\alpha$ ,5 $\alpha$ ,10 $\alpha$ -triacetylcholanolic acid obtained in Example 5, instead of 3 $\alpha$ -acetylcholanolic acid, to obtain 3 $\alpha$ ,5 $\alpha$ ,10 $\alpha$ -triacetyloxyethyl lithocholate of Formula 7 (yield : 71%).

## II. Synthesis of Photoresist Polymer

Preparation Example 1--Synthesis of Poly(tert-butyl 5-norbornene-2-carboxylate / 2-hydroxyethyl 5-norbornene-2-carboxylate / 5-norbornene-2-carboxylic acid / maleic anhydride)

- 5 To tetrahydrofuran or toluene was added 0.5 to 0.95 mole of tert-butyl 5-norbornene-2-carboxylate, 0.05 to 0.8 mole of 2-hydroxyethyl 5-norbornene-2-carboxylate, 0.01 to 0.2 mole of 5-norbornene-2-carboxylic acid, 0.5 to 1 mole of maleic anhydride and 0.5 to 10g of 2,2'-azobisisobutyronitrile (AIBN).

- 10 The mixture was stirred at 60 to 70°C for 4 to 24 hours under a nitrogen or argon atmosphere. The resulting polymer was precipitated in ethyl ether or hexane, and dried to obtain the title polymer of Formula 10.

Preparation Example 2--Synthesis of Poly(tert-butyl 5-norbornene-2-carboxylate / 3-hydroxypropyl 5-norbornene-2-carboxylate / 5-norbornene-2-carboxylic acid / maleic anhydride)

- 15 The procedure of Preparation Example 1 was repeated but using 3-hydroxypropyl 5-norbornene-2-carboxylate, instead of 2-hydroxyethyl 5-norbornene-2-carboxylate, to obtain the title polymer of Formula 11.

- 20 Preparation Example 3--Synthesis of Poly(tert-butyl 5-norbornene-2-carboxylate / 2-hydroxyethyl 5-norbornene-2-carboxylate/5-norbornene-2,3-dicarboxylic acid / maleic anhydride)

The procedure of Preparation Example 1 was repeated but using 5-norbornene-2,3-dicarboxylic acid, instead of 5-norbornene-2-carboxylic acid, to obtain the title polymer of Formula 12.

### III. Preparation of Photoresist Composition

#### Example 7

To propyleneglycol methyl ether acetate (100g) was added the polymer of formula 10 (10g), the compound of formula 2 (0.2g), and triphenylsulfonium triflate (0.1g). The mixture was then stirred and filtered through a 0.20 $\mu$ m filter to obtain a photoresist composition.

#### Example 8

To propyleneglycol methyl ether acetate (100g) was added the polymer of formula 11 (10g), the compound of formula 3 (0.2g), and triphenylsulfonium triflate (0.1g). The mixture was then stirred and filtered through a 0.20 $\mu$ m filter to obtain a photoresist composition.

#### Example 9

To propyleneglycol methyl ether acetate (100g) was added the polymer of formula 12 (10g), the compound of formula 4 (0.2g), and triphenylsulfonium triflate (0.1g). The mixture was then stirred and filtered through a 0.20 $\mu$ m filter to obtain a photoresist composition.

#### Example 10

To propyleneglycol methyl ether acetate (100g) was added the polymer of formula 13 (10g), the compound of formula 7 (0.2g), and triphenylsulfonium triflate (0.1g). The mixture was then stirred and filtered through a 0.20 $\mu$ m filter to obtain a photoresist composition.

### IV. Formation of Photoresist Pattern

#### Example 11

The photoresist composition prepared in Example 7 was coated on a wafer, baked at 100°C for 90 seconds and exposed to light using a 0.60NA KrF exposing device (Nikon S201). The photoresist composition was post-baked at 130°C for 90

seconds and developed in 2.38wt% aqueous TMAH solution to obtain a 200nm L/S pattern (see Fig. 1). The resulting pattern was flow baked at 153°C for 90 seconds to obtain a 150nm L/S pattern (see Fig. 2).

#### Example 12

5        The procedure of Example 11 was repeated but using the photoresist composition prepared in Example 8, to obtain a 130nm L/S pattern.

#### Example 13

The procedure of Example 11 was repeated but using the photoresist composition prepared in Example 9, to obtain a 100nm L/S pattern.

10       Example 14

The procedure of Example 11 was repeated but using the photoresist composition prepared in Example 10, to obtain a 150nm L/S pattern.

As discussed earlier, the additive of the present invention improves the flow property of the photoresist polymer for ArF which is not suitable for the resist flow process due to its high glass transition temperature, thus enabling the photoresist composition to be easily thermally flown. That is, the photoresist composition containing the additive can be suitably employed for the resist flow process for forming the contact hole.

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The foregoing discussion of the invention has been presented for purposes of illustration and description. The foregoing is not intended to limit the invention to the form or forms disclosed herein. Although the description of the invention has included description of one or more embodiments and certain variations and modifications, other variations and modifications are within the scope of the invention, e.g., as may be within the skill and knowledge of those in the art, after understanding the present disclosure. It is intended to obtain rights which include alternative embodiments to the extent permitted, including alternate, interchangeable and/or

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equivalent structures, functions, ranges or steps to those claimed, whether or not such alternate, interchangeable and/or equivalent structures, functions, ranges or steps are disclosed herein, and without intending to publicly dedicate any patentable subject matter.

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